(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 516 263 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **92300264.6**

(22) Date of filing: **13.01.92**

(51) Int. Cl.[5]: **H01S 3/103**, H01S 3/25, H01S 3/085

(30) Priority: **27.05.91 JP 121448/91**

(43) Date of publication of application: **02.12.92 Bulletin 92/49**

(84) Designated Contracting States: **DE FR GB**

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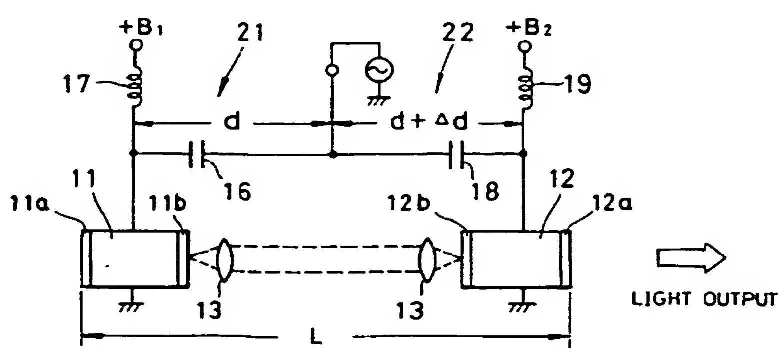
(54) **Light pulse generator.**

(57) A light pulse generator is provided comprising first (11) and second (12) semiconductor laser diodes, each having a highly reflective surface (11a,12a) and a non-reflective surface (11b,12b) arranged opposite to each other, an optical system developed between the highly reflective surfaces (11a,12a) of the first (11) and second (12) semiconductor laser diodes with the two non-reflective surfaces (11b,12b) being confronted by each other, and a current supplying means (16,17;18,19) for feeding the first (11) and second (12) semiconductor laser diodes with two discrete high-frequency currents respectively which repeat at intervals of a period equal to n times (n is an integer) the duration of light traveling one cycle within the optical resonator and have a phase difference of π/n from each other. Accordingly, the light pulse generator can produce a series of short-width light pulses while minimizing the generation of unwanted sub pulses.

FIG. 3



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The present invention relates to a light pulse generator provided with small-sized semiconductor laser diodes for generating a series of light pulses with high peak power and short pulse width.

A typical light pulse generator is shown in Fig. 1.

As shown, a semiconductor laser diode 1 has at one end a highly reflective surface 1a and at the other end a non-reflective surface 4. The non-reflective surface 4 is finished with a non-reflection coating for minimizing the reflectance on the outer surface of the laser diode.

A lens 2 is arranged in such a position that the semiconductor laser diode 1 is optically coupled to a reflecting mirror 3 for forming an optical resonator. More specifically, the highly reflective surface 1a, the lens 2, and the reflecting mirror 3 are arranged to serve in combination as an optical resonator for permitting the semiconductor laser diode 1 to produce mode locked oscillation. The semiconductor laser diode 1 is arranged to be supplied with a mode synchronizing high-frequency current from a capacitor 6 and a bias direct current from an inductance coil 7.

The action of the prior art light pulse generator will now be described. Upon receiving a DC bias current from the coil 7 and a high-frequency current, of which the frequency is f ($f=c/2L$ where L is the resonator length and c is the velocity of light), from the capacitor 6, the semiconductor laser diode 1 generates a series of light pulses P at regular intervals of 1/f, as shown in Fig. 2. It is known that this type of light pulse generator produces a series of short pulses at about the threshold of oscillation of its semiconductor laser diode, as shown in Fig. 2-a. However, when the feeding current is increased for enhancement of the output, unwanted sub pulses are also developed at a frequency corresponding to the length l of the semiconductor laser diode (See Fig. 1) or at intervals of 2l/c due to residual reflection (0.1 to 1 % commonly) on the non-reflective coating 4 of the semiconductor laser diode, thus increasing the pulse width as shown in Fig. 2-b.

The present invention has been invented for the purpose of elimination of the foregoing drawback of the prior art light pulse generator and its object is to provide an improved light pulse generator capable of producing a series of short-width light pulses with high peak power.

The light pulse generator according to the present invention comprises: two, first and second, semiconductor laser diodes, each having a highly reflective surface and a non-reflective surface arranged opposite to each other; an optical system developed between the highly reflective surfaces of the first and second semiconductor laser diodes with the two non-reflective surfaces being confronted by each other; and a current supplying means for feeding the first and second semiconductor laser diodes with two discrete high-frequency currents respectively which repeat at intervals of a period equal to n times (n is an integer) the duration of light traveling one cycle within the optical resonator and have a phase difference of π/n from each other.

In operation the two semiconductor laser diodes complement each other thus attenuating unwanted sub pulses.

One preferred embodiment of the present invention will now be described by way of example only with reference to the accompanying drawings, in which:

Fig. 1 is a schematic view of a prior art light pulse generator;

Fig. 2 is a graphic diagram showing the waveforms of two light pulse outputs produced by the prior art light pulse generator in low- and high-magnitude operation respectively;

Fig. 3 is a schematic view showing one embodiment of the present invention;

Fig. 4 is a graphic diagram explaining the generation of light pulses by the embodiment of the present invention; and

Fig. 5 is a graphic diagram showing the pulse width and average light output produced by the embodiment of the present invention.

Fig. 3 illustrates a light pulse generator according to the present invention, which comprises a first semiconductor laser diode 11 having at one end a highly reflective surface 11a and at the other end a non-reflective surface 11b, a second semiconductor laser diode 12 having at one end a highly reflective surface 12a and at the other end a non-reflective surface 12b, and a couple of lenses 13, 13 arranged to optically couple the two, first and second, semiconductor laser diodes 11 and 12 to each other for forming an optical resonator. More specifically, the first 11 and the second semiconductor laser diode 12 are adapted to receive from each other beams of output light which are emitted from the non-reflective surfaces 12b and 11b respectively and transmitted through the two lenses 13, 13, thus being optically coupled to each other by an optical system.

The light beams are amplified during traveling between the two highly reflective surfaces 11a and 12a of their respective first and second semiconductor laser diodes 11 and 12 or by an optical resonator which has an optical length of L extending between the two highly reflective surfaces 11a and 12a. In other words, the optical resonator is composed of the two lenses 13, 13 and the two highly reflective surfaces 11a and 12a for permitting the first 11 and the second semiconductor laser diode 12 to produce mode locked oscillation.

Also, the light pulse generator has a current supplying means for feeding a mode synchronizing high-frequency current through a capacitor 16 and a bias DC current through an inductance coil 17 to the first semiconductor laser diode 11. Similarly, the second semiconductor laser diode 12 is fed by the current supplying means with a mode synchronous high-frequency current through a capacitor 18 and a bias DC current through an inductance coil 19. The high-frequency current supplied from the current supplying means has the same frequency as of the prior art which is expressed as $f = c/2L$ - (where c is the velocity of light and L is the length of the resonator). In particular, the high-frequency current is supplied from a high-frequency current source via a first 21 and a second high-frequency current cable 22 to two bias current lines coupled to their respective first and second semiconductor laser diodes 11, 12.

As shown in Fig. 3, the first 21 and the second high-frequency current cable 22 of the current supplying means which are connected to the first and second semiconductor laser diodes 11, 12 respectively, are adapted to have a length d and a length $d+\Delta d$ respectively so that two high-frequency currents having a frequency f and supplied to the first and second semiconductor laser diodes 11, 12 together with DC bias currents are in opposite phase to each other. More particularly, the second high-frequency current cable 22 acts as a delay line.

As set forth above, the two semiconductor laser diodes of the light pulse generator of the present invention are arranged with their respective non-reflective surfaces distanced from each other for optical coupling and allows their respective highly reflective surfaces to act as optical resonating surfaces thus forming an optical resonator. In action, high-frequency currents recurring at regular intervals of a period equal to the duration of light traveling one cycle within the resonator are fed to the two semiconductor laser diodes with a time lag of half the period inbetween.

The action of the light pulse generator of the present invention will now be described.

When given rates of DC bias and high-frequency currents are supplied to the two, first and second, semiconductor laser diodes 11, 12, light pulses are generated and cycled between the two highly reflective surfaces 11a and 12a of the optical resonator, as shown in Fig. 3. As the two high-frequency currents supplied to their respective semiconductor laser diodes 11 and 12 are in opposite phase to each other as best shown in Figs.4-a and 4-b, the resultant light pulses are modulated in the positive direction (the upward direction in Figs.4-a and 4-b) or gain amplified during passing through the two semiconductor laser diodes 11 and 12. As the highly reflective surface 12a has a partially reflective coating, the light pulses are shaped as shown in Fig. 4-c.

It is understood that when the bias current to the second semiconductor laser diode 12 is smaller than that to the first semiconductor laser diode 11, the generation of sub pulses is prevented by the gate effect of the second semiconductor laser diode 12 regardless of an increase in the bias current to the first semiconductor laser diode 11 and thus, a series of short-width light pulses with high peak power are produced.

Figs. 5-a and 5-b show the relation of a bias current of the first semiconductor laser diode 11 to resultant measurements of the pulse width and the average optical output. As apparent, the shortest light pulse which is about 7 ps in the pulse width and has a frequency of 1 GHz at 1.19 mW average output and 170 mW peak output is generated when the bias currents to the first 11 and the second semiconductor laser diode 12 are 90 mA and 25 mA respectively and also, the high-frequency currents to the same is 110 mAp-p.

Although the modulation frequency is f corresponding to the length of a period ($f = c/2L$) in the embodiment, it may be an integer multiple of f or $f' = nc/2L$ (where n is an integer) while the phase difference between the two feeding currents to the first 11 and the second semiconductor laser diode 12 is π/n. In this case, the frequency of a generated light pulse waveform is equal to f'.

Accordingly, the light pulse generator of the present invention has the two non-reflective surfaces of their respective first and second semiconductor laser diodes arranged optically opposite to each other so that when two phase-opposite currents are fed to the first and second semiconductor laser diodes respectively, a series of light pulses of short width and high magnitude can be produced while the generation of unwanted sub pulses is minimized.

Claims

1. A light pulse generator comprising:

   first and second semiconductor laser diodes, each having a highly reflective surface and a non-reflective surface arranged opposite to each other;

   an optical resonator developed between the highly reflective surfaces of the first and second semiconductor laser diodes with the two non-reflective surfaces being towards each other;and

   a current supplying means for feeding the first and second semiconductor laser diodes with respective discrete high-frequency currents which repeat at intervals of a period

equal to n times (n is an integer) the duration of light traveling one cycle within the optical resonator and have a phase difference of π/n from each other.

2. A light pulse generator according to Claim 1, wherein two bias currents for supply to the first and second semiconductor laser diodes respectively are different in amplitude from each other.

FIG.1

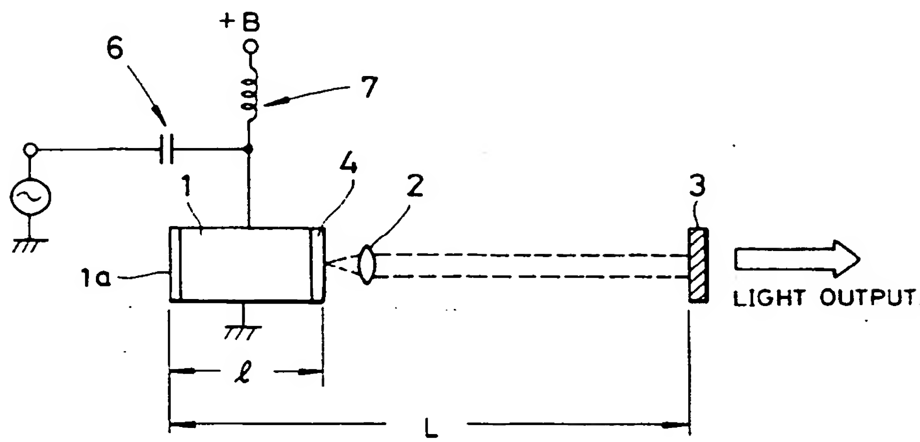

+B
6
7
4
1
2
3
1a
LIGHT OUTPUT
ℓ
L

FIG.2

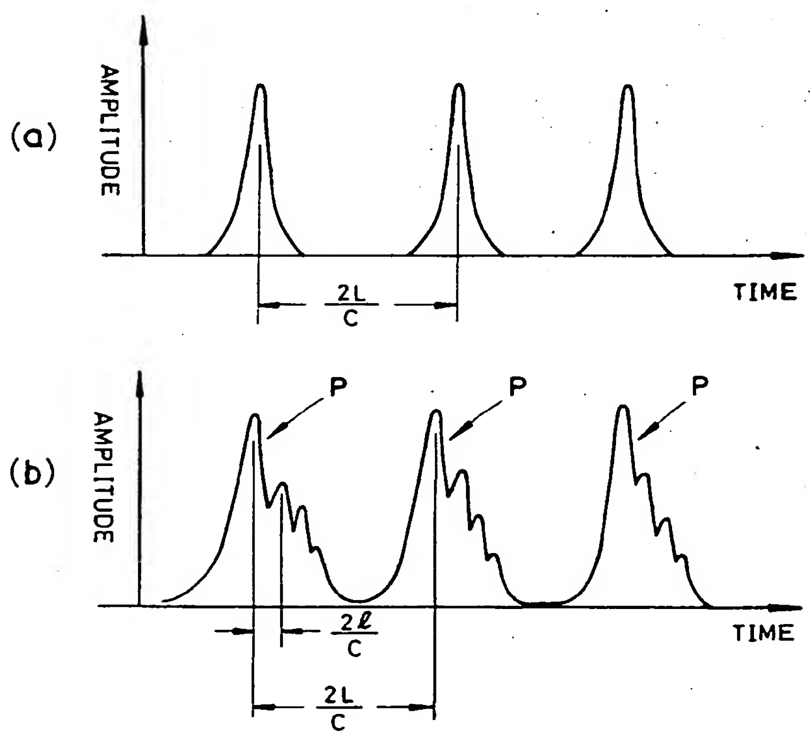

(a)
AMPLITUDE
TIME
2L/C
(b)
AMPLITUDE
P
P
P
TIME
2ℓ/C
2L/C

FIG. 3

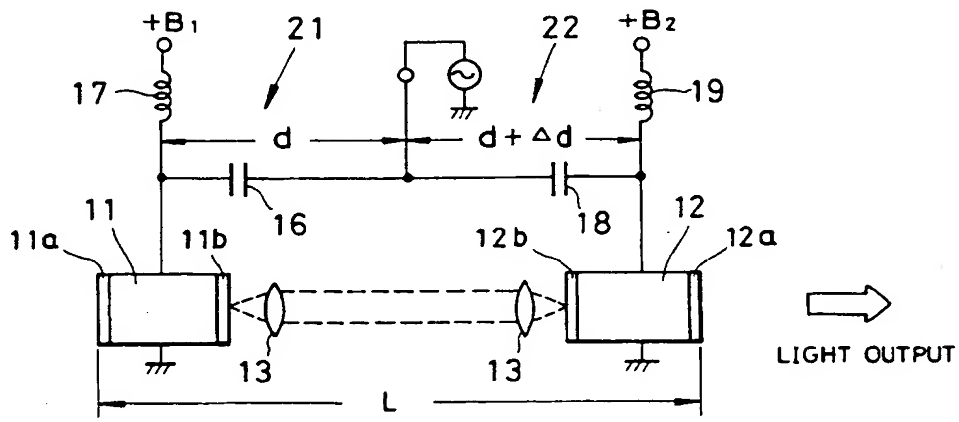

+B1
21
22
+B2
17
19
d
d + Δd
16
18
11
12
11a
11b
12b
12a
13
13
L
LIGHT OUTPUT

FIG. 4

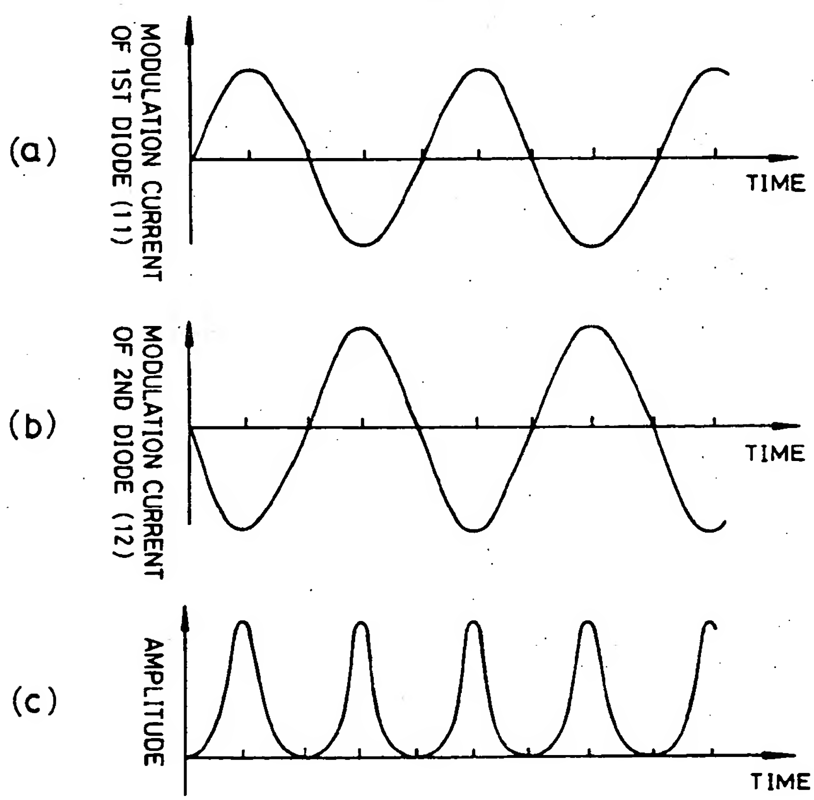
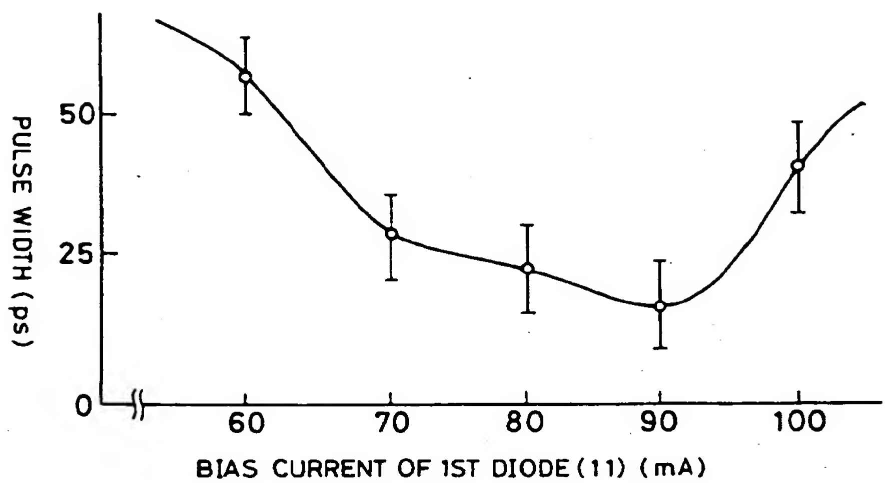
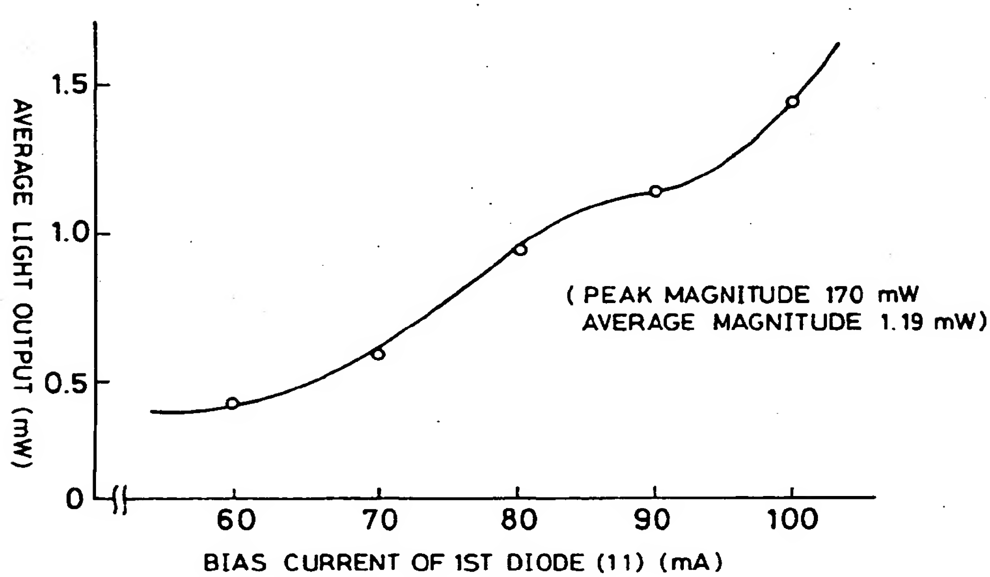

(a)
MODULATION CURRENT OF 1ST DIODE (11)
TIME
(b)
MODULATION CURRENT OF 2ND DIODE (12)
TIME
(c)
AMPLITUDE
TIME

FIG. 5

(a)


PULSE WIDTH (ps)
50
25
0
60
70
80
90
100
BIAS CURRENT OF 1ST DIODE (11) (mA)

(b)


AVERAGE LIGHT OUTPUT (mW)
1.5
1.0
0.5
0
60
70
80
90
100
BIAS CURRENT OF 1ST DIODE (11) (mA)
(PEAK MAGNITUDE 170 mW
AVERAGE MAGNITUDE 1.19 mW)

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(88) Date of deferred publication of the search report: **23.12.92 Bulletin 92/52**

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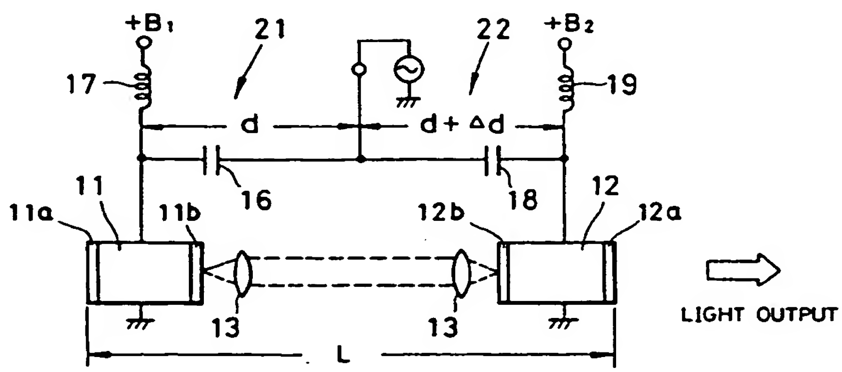

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Application Number

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Page 1

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A	JOURNAL OF LIGHTWAVE TECHNOLOGY. vol. 7, no. 2, February 1989, NEW YORK US pages 400 - 419 K.Y. LAU 'Short pulse and high frequency signal generation in semiconductor lasers' * chapters I-III; figure s 1,3* ---	1	H01S3/103 H01S3/25 H01S3/085 H01S3/098
A	IEEE JOURNAL OF QUANTUM ELECTRONICS. vol. 25, no. 6, June 1989, NEW YORK US pages 1426 - 1439 J.E BOWERS ET AL 'Actively mode locked semiconductor lasers' *chapters I,II; figures 1-6* ---	1	
A	ELECTRONICS LETTERS. vol. 20, no. 15, 19 July 1984, STEVENAGE, HERTS, GB pages 624 - 625 G. EISENSTEIN ET AL 'InGaASP 1.3 mum optical amplifier modulator integrated with a fibre resonator mode locked laser' * the whole document * ---	1,2	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	APPLIED PHYSICS LETTERS. vol. 58, no. 20, 20 May 1991, NEW YORK US pages 2214 - 2216 Y. OZEKI ET AL 'POlarization switching and bistablity in an external cavity laser with a polarization sensitive saturable absorber' * the whole document * ---	1,2	H01S
A	EP-A-0 117 734 (AT&T) * the whole document * --- -/--	1,2	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	08 OCTOBER 1992	CLAESSEN L.M.

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons

& : member of the same patent family, corresponding document

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Application Number

EP 92 30 0264
Page 2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
P,X	JAPANESE JOURNAL OF APPLIED PHYSICS, PART 2, LETTERS. vol. 30, no. 8A, June 1991, TOKYO JP pages L1402 - L1405 H. KAWAGUCHI ET AL 'Picosecond optical pulse generation from mutually coupled laserdiodes by synchroneous pump mode locking' * the whole document * -----	1,2	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

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